NAVAL HEALTH RESEARCH CENTER

PREDICTORS OF STRESS FRACTURE SUSCEPTIBILITY IN YOUNG FEMALE RECRUITS

R. A Shaffer
M. J. Rauh
S. K. Brodine
D. W. Trone
C. A. Macera

Reportt No. 04-30

NAVAL HEALTH RESEARCH CENTER
P. O. BOX 85122
SAN DIEGO, CA 92186-5122

BUREAU OF MEDICINE AND SURGERY (M2)
2300 E ST. NW
WASHINGTON, DC 20372-5300

Predictors of Stress Fracture Susceptibility in Young Female Recruits

Richard A Shaffer[1,2]

Mitchell J. Rauh[2,3,4]

Stephanie K. Brodine[2,4]

Dan W. Trone[1,5]

Caroline A. Macera[2,4]

[1]Behavioral Science & Epidemiology Program
Musculoskeletal Injury Epidemiology
Naval Health Research Center
P.O. Box 85122
San Diego, CA. 92186-5122

[2]Graduate School of Public Health
San Diego State University

[3]Graduate Program in Orthopaedic & Sports Physical Therapy
Rocky Mountain University of Health Professions

[4]GEO-CENTERS, INC.
7 Wells Avenue
Newton Centre, MA

[5]University of California, San Diego/San Diego State University
Joint Doctoral Program in Public Health Epidemiology

Word Count: Abstract: 237; Text: 3468 References: 32; Tables: 6

Report No. 04-30 was supported by the Office of Naval Research, Arlington, VA, under Work Unit No. 60213, document NC 2275 M0001802WR20006. The views expressed in this manuscript are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government. Approved for public release; distribution is unlimited. Human subjects participated in this study after giving free and informed consent. This research has been conducted in compliance with all applicable federal regulations governing the protection of human subjects in research.

ABSTRACT

Background: Stress fractures account for substantial morbidity for young women undergoing US Marine Corps basic training.

Hypothesis: Certain pretraining characteristics identify women at increased risk of stress fractures during boot camp.

Study Design: Prospective. Recruits were followed throughout the 13 weeks of boot camp for occurrence of stress fractures.

Methods: Data collected included baseline performance on a timed run, anthropometric measurements, and a baseline questionnaire highlighting exercise and health habits among 2962 women undergoing basic training at the Marine Corps Recruit Depot (MCRD), Parris Island, in 1995-96.

Results: One hundred and fifty-two recruits (5.1%) had 181 confirmed lower extremity stress fractures, with the most common sites being the tibia (25%), metatarsals (22%), pelvis (22%), and femur (20%). Logistic regression models revealed that low physical fitness (a slower time on the initial run test) and no menses during the past year were significantly associated with the occurrence of any stress fracture during boot camp. Similarly, lower physical fitness and no menses during the past year were also predictive of pelvic/femoral stress fracture.

Conclusions: These findings suggest that stress fractures may be reduced if women entering MCRD training participated in pretraining activities designed to improve aerobic fitness. Furthermore, women reporting no menses during the previous year may need additional observation during training.

Clinical Relevance: Consistent with previous studies, we found that low aerobic fitness was the only modifiable risk factor associated with stress fractures during boot camp.

Key Terms: injuries, menstrual problems, military, women

INTRODUCTION

Musculoskeletal injuries are a serious problem for recruits participating in military training, but may be especially important for women. Prospective studies of military populations participating in different entry-level programs have consistently reported higher injury rates among women than men.[5,9,16,18,19,30] In particular, estimates of stress fracture rates of 5-12% have been reported among women undergoing various entry-level military training programs, rates that are about twice as high as those reported for men undergoing the same training.[4,16]

Despite the general knowledge that stress fractures cause significant morbidity during military recruit training, little is known about the risk factors for stress fractures, especially among women. A lower level of physical aerobic fitness prior to recruit training has been consistently identified as a risk factor among women in previous military studies.[4,16,32] Although less studied, other risk factors for injury that have been observed among women are history of smoking,[1,19] excessive alcohol drinking,[21] history of menstrual dysfunction,[12,32] white race,[21] and anatomical factors such as narrow tibial cortice,[4] narrow pelvis[32] and smaller thigh muscle girth.[4] Potential risk factors such as age[14,32] and body mass[21,22] appear equivocal in young military training populations.

Knowledge of risk factors for stress fractures is essential if they are to be prevented. Intrinsic risk factors have been incorporated into a predictive model for musculoskeletal injury among men undergoing Marine Corps recruit training.[29] The analysis of these risk factors indicates that as much as 60% of the stress fractures during this training can be predicted from various measures of fitness, body structure, prior injury history, and exercise history.[29] The strongest predictor, the baseline fitness of the recruit, is modifiable and suggests that improvement of fitness prior to training may reduce stress fractures during training.

The objective of the present study was to identify risk factors that could be used to derive predictive models for overall lower extremity stress fracture and for the more severe pelvic/femoral stress fracture in female military personnel. These models were constructed from items in a questionnaire, which focused on the exercise and health habits prior to recruit training, as well as a fitness measure and assessment of body composition. Ultimately an abbreviated profile will be constructed that can be utilized as a screening tool to identify women at high risk for stress fractures during training, and to suggest successful interventions to reduce the incidence of the stress fractures that occur during training.

MATERIALS AND METHODS

Subjects

Of the 3249 female Marine Corps recruits ages 17 to 33 years who arrived at the Parris Island Marine Corps Recruit Depot (MCRD) from March 1995 to September 1996, 2962 recruits (91.2%) volunteered to take part in this study. All potential participants were briefed on the study and those who volunteered received the privacy act statement and consent form according to the guidelines of the Institutional Review Board of the Naval Health Research Center, San Diego, Calif.

Outcome Data

All volunteers were followed throughout basic training for occurrence of lower extremity musculoskeletal injuries, with specific attention to stress fractures. Stress fracture data were gathered from reviewing each subject's medical record at the completion of training or time of separation from MCRD. The injury data extracted from the medical records included date of visit and onset of injury, injury site, specific final diagnosis, total visits for the diagnosis, and the nature and duration of restricted duty due to injuries. The senior medical officer at the Branch

Medical Clinic routinely confirmed all stress fractures among the subjects either radiographically or scintigraphically. Stress fractures were defined as partial or complete fatigue fractures of insidious onset in nondiseased bone. Diagnosis of stress fracture was based on (1) clinical presentation of localized pain of insidious onset, without prior acute trauma, aggravated by repetitive weight-bearing activities and relieved with rest; and (2) a confirmatory (+) radiograph and/or bone scan at a site consistent with the clinical presentation. A positive (+) radiograph was defined as presence of periosteal reaction, endosteal callus formation, and/or a fracture line in an otherwise normal bone. A positive bone scan was defined as the presence of 3+ to 4+ intensity localized fusiform uptake at the site of pain. For analysis purposes, a woman was considered as a single case having a stress fracture if she had one or more confirmed stress fracture.

Physical Fitness Measurements

Performance on a three-quarter or 1-mile timed run, a component of the Marine Corps Initial Strength Test that was conducted prior to the start of training, determined the entry level of physical fitness. The run times were categorized into quartiles within each distance, with quartile 1 consisting of the fastest runners (referent group) and quartile 4 consisting of the slowest runners.

Anthropometric measurements. Anthropometric measurements included height and weight as continuous values and as categorized into tertiles. Body mass index (BMI) was calculated from weight in kilograms and height in meters as weight/height^2. For weight, height, and BMI variables, values 1 standard deviation from the mean were categorized into lower and higher risk tertiles, with the middle group as the referent group.

Questionnaire measurements. Basic information on age and race/ethnicity was obtained from the questionnaire. Age was used as a continuous variable. Black women were the referent

group since previous literature suggests they are at lower risk of bone injury than white or Hispanic women.[20] The questionnaire also addressed history of previous stress fractures or other lower extremity overuse injuries, prior and recent physical activity and fitness practices, and menstrual history. Those without a prior history of either stress fractures or overuse injuries were the referent group. Self-rated fitness of excellent or very good was the referent group compared with those who rated their fitness as good, or fair/poor. Several questions were asked to assess the type of physical activity the women participated in during the 2 months prior to entering MCRD training. These questions assessed exercise or sports participation, running behavior, including weekly mileage, frequency, and duration. For all variables, the group with the highest level of activity was the referent group.

Menstrual dysfunction was examined by age at menarche ($\leq$12 years old as the referent group) and several determinations of menstrual dysfunction: (1) number of menses during past year, with 10-12 menses considered as the referent group; and (2) secondary amenorrhea (menses for at least 6 consecutive months as the referent group).[28] Other information on oral contraceptive use and pregnancy status during the past 12 months was also available.

Analysis. Means and standard deviations for continuous variables, such as age, height, weight, BMI, and mean age of menarche were calculated by stress fracture status to document personal characteristics. Statistical comparisons of mean values were performed with *t* tests.

Risks of stress fracture injury were calculated as the incidence (percentage) of recruits with at least one lower extremity stress fracture (or pelvic/femoral stress fracture) divided by the total number of subjects. Odds ratios (ORs) were calculated comparing the proportion of individuals in a high-risk group with the proportion of individuals in a baseline or referent group for each of the potential risk factors.

For multivariate analyses, the measure of association was the adjusted odds ratios, which were generated from a multiple logistic regression analysis. Items included in the logistic regression model analyses were selected from those with significant univariate associations or those known to possibly confound the risk relationship. For univariate and multivariate analyses of women's report of menstrual history during the past 12 months before basic training, women who reported being pregnant during the preceding 12 months prior to training were excluded from the analyses.

RESULTS

Stress Fractures

During the 13 weeks of Marine Corps basic training, 152 of the 2962 women (5.1%) suffered a total of 181 stress fractures. Sixty-nine (2.3%) of the women incurred a pelvic/femoral stress fracture. The most common sites of stress fractures were the tibia (25%), metatarsals (21.7%), pelvis (21.7%), and femur (20%) (Table 1).

Subjects

The 2962 women had a racial/ethnic distribution of 69.0% white, 18.4% black, 9.7% Hispanic, and 2.9% other ethnicity/race. The mean characteristics for continuous variables (age, height, weight, BMI, age at menarche) are reported in Table 2 for the total sample and by stress fracture status. Those with stress fractures were not statistically significantly different from those without stress fractures on any of the continuous demographic or menstrual characteristics.

Risk Factors

The incidence and risk of stress fracture associated with categorical variables including age, race/ethnicity or body stature (height, weight, BMI), and prior injury are shown in Table 3. The Hispanic women in our study were almost twice as likely to incur a stress fracture as black

women [OR = 1.97; 95% confidence interval (CI), 1.1-3.7]. Although Asian women were at least twice as likely to incur a stress fracture, especially pelvic or femoral stress fracture, no significant associations were found, possibly due to the small sample size for this group. No significant differences were found for age, across tertiles of body stature variables, or for prior injuries.

Table 4 displays the incidence and risk of overall and pelvic/femoral stress fracture by measures of physical fitness and levels of self-assessed activity. Women in the two slowest run-time quartiles were approximately 3.5 times more likely to incur a stress fracture than women in the fastest run time quartile [quartile 3: OR = 3.45; 95% CI, 2.0-6.1; quartile 4 {slowest): OR = 3.63; 95% CI, 2.1-6.4). Specific to pelvic/femoral stress fracture, women in the slowest quartiles were 3 to 4 times more likely to incur a pelvic/femoral stress fracture as compared with women in the fastest quartile [quartile 3: OR = 4.23; 95% CI, 1.7-10.4; quartile 4 (slowest): OR = 3.27; 95% CI, 1.3-8.2].

Women who rated their current fitness as fair or poor were twice as likely to incur a stress fracture as women who rated their current fitness as excellent or very good (OR = 2.00; 95% CI, 1.2-3.3). Finally, during the 2 months prior to basic training, nonrunners or women who reported running less than 1.5 miles per run were more likely to incur a stress fracture (OR = 2.41; 95% CI, 1.3-4.4) than women who ran 3 or more miles per run. Similarly, nonrunners were twice as likely to incur a stress fracture as women who ran 4 or more times a week (OR = 2.17; 95% CI, 1.0-4.5).

Among measures of reproductive history and birth control pill use, only women who reported a late age at menarche (after age 12) or no menses in the past year were at increased risk of stress fracture injury (Table 5). Women with a later onset of menarche (13 years or older)

were almost 1.5 times (OR = 1.44; 95% CI, 1.0-2.0) more likely to incur a stress fracture than women whose menarche started at a younger age. Women who reported a pregnancy in the 12 months prior to training (n = 146) were excluded from the analyses on menstrual function. Women who reported having no menses during the 12 months prior to training were over 5 times more likely (OR = 5.64; 95% CI, 2.2-14.4) to incur a stress fracture and over 8 times more likely (OR = 8.54; 95% CI, 2.8-25.8) to incur a pelvic/femoral stress fracture than women who reported eumenorrhea (10-12 menses during the past 12 months). Women who were considered to have secondary amenorrhea (6 or more consecutive missed menses past year) were over 2 times more likely (OR = 2.53; 95% CI, 1.1-6.0) to incur a pelvic fracture than women considered eumenorrheic. Women who reported a pregnancy in the 12 months prior to training (n = 146) were excluded from the analyses on menstrual function. No significant associations were found for birth control pill use.

After adjusting for age and other potential factors that were found to be associated with risk of stress fracture, the final logistic regression model for overall stress fracture included slow initial run time (quartile 3 [slow]: OR = 3.41; 95% CI, 1.9-6.1), quartile 4 [slowest]: OR = 3.54; 95% CI, 2.0-6.3) and no menses in past year (OR=3.79; 95% CI, 1.3-10.7). Ethnicity, running frequency and mileage (during the two months prior to basic training), self-rated fitness, and late menarche (after age 12) were not significantly associated with stress fracture occurrence in the final model (Table 6). Specific to pelvic/femoral stress fractures, only slow initial run time [quartile 3 (slow): OR = 3.89; 95% CI, 1.6-9.6], quartile 4 (slowest): OR = 3.14; 95% CI, 1.2-9.0] and no menses in past year (OR = 5.85; 95% CI, 1.7-20.8) were included in the final model after adjusting for age and ethnicity (Table 6).

DISCUSSION

The purpose of this study was to determine risk factors for stress fracture during basic training among women undergoing Marine Corps basic training. This study documents that approximately 5% of the women incurred a stress fracture during 13 weeks of basic training. In addition to low physical fitness at entry, women reporting no menses during the past year were at increased risk of stress fracture.

The type of stress fracture injury (over 40% of the fractures were pelvic or femoral fractures) was more severe in this cohort of female Marine recruits than has been reported in civilian athletes or male military recruits. Pelvic stress fractures are relatively rare in civilian male and female athletes, representing 1-2% of all stress fractures,[24] and are uncommon among male recruits undergoing similar physical training.[3] More importantly, pelvic and femoral stress fractures can be particularly devastating since they typically require a more prolonged rehabilitation period (approximately 4 months compared with 1-2 months for tibial, fibular or metatarsal stress fractures)[7,15] and have a higher frequency of complications, including delayed union and nonunion.[26,27]

We found that low physical aerobic fitness, as measured by the timed run, was strongly associated with consequent stress fracture injury. As the run time increased (slower runners), the risk of stress fracture increased. Recruits who had the slowest times on the test (quartile 1) were almost 3 times more likely to incur a stress fracture than those with the fastest times (quartile 4). This finding is consistent with three other studies which have reported that slower run times are associated with greater risk of lower extremity injury among women undergoing military training.[6,9,16] In contrast, while Jones et al. found a lower self-rated physical fitness levels to be associated with injury among men, they did not find the same association among women.[16] It seems logical that low physical fitness as measured by running time would be associated with a

higher risk of injury during Marine Corps training because recruits must repeatedly perform activities such as walking, marching, or running that might increase the overuse mechanism on the musculoskeletal system. Those who were more aerobically fit may be protected from injury because they may have had performed similar types of activities that allowed the body to adapt to the increasingly intense demands on the musculoskeletal system that occurs during military training.

Although not significant after controlling for initial run, we found that women who did not run or reported running less than an average of 1.5 miles per run were also at increased risk of overall stress fracture. This finding is similar to that of a study of female Marine Corps Officer candidates who also found a higher incidence of stress fracture for women who ran 2.8 miles or less prior to entering officer training.[32] Finally, running 3 or fewer times per week and self-rated fitness level variables also were no longer significant after being controlled for initial run time in the final logistic model. These finding suggests that previous fitness levels or activity at higher levels may protect women from stress fracture injury associated with Marine Corps basic training.

Consistent with previous reports,[10,13,17,21] we found the lowest rates of stress fractures among black women undergoing military training. We also found that Hispanic women were twice as likely to suffer a stress fracture as compared with black women, although this was not significant in the final adjusted model. Another study of pelvic stress fractures among naval female recruits also observed Hispanic women to have significantly higher incidence of pelvic stress fracture than black women.[17] We also observed a higher (not statistically significant) incidence rate of stress fracture among Asian and white women compared with black women, which has been reported by others.[10,13,17,21] It has been surmised that lower stress fracture risk

among black women may be related to their higher bone density[7] or to different biomechanical features that may protect against stress fracture development.[7] Further research is needed to understand the relationship between race/ethnicity and stress fracture risk.

While no trend in stress fracture incidence was apparent by number of menses in the past year, women who reported no menses in the past year had a 4-fold greater likelihood of stress fracture than women who reported 10-12 menses; the likelihood was 8-fold greater for women who incurred a pelvic or femoral stress fracture. To our knowledge, no study has reported secondary amenorrhea as a risk factor for pelvic/femoral or other type of stress fracture. Although not significant in the final model, female recruits who reported secondary amenorrhea (women missing 6 or more consecutive menses) were at higher risk for pelvic/femoral stress fracture. Also not significant in our final logistic model, women who reported menarche occurring after age 12 had a greater likelihood of developing a stress fracture during training, which is consistent with the finding of several athlete studies among women.[8,11,31] Our finding is in contrast to a study of women training as Marine Corps Officer candidates where no association was found between age of menarche and stress fracture incidence.[21] Similar to the findings on secondary amenorrhea, we are unaware of any study in military setting that has reported a delayed onset of menses as a risk factor for stress fracture. Other studies of women undergoing military training[12,32] and athletes[2,8,23] suggest that menstrual disturbances are acting to confer an increase risk of stress fracture in these women. While we did find that women who reported no menses during the past year were at increased risk for stress fractures, we did not find a linear trend by number of menses in the past year, so there is limited support from this study for that hypothesis. Finally, unlike other studies, the results of the present study do not support the finding that use of oral contraception protects against stress fracture.[2,25]

We found that in this young population, age was not associated with stress fracture. While some studies have found a younger age to be a possible risk factor for stress fracture,[20,32] others have found older age to increase the risk of stress fracture.[14,20] Thus, age as a risk factor for stress fracture remains equivocal and deserves further investigation.

In our study, other potential risk factors such as height, body weight, and BMI were not found to be significantly associated with stress fracture risk. While others have found risk associations between stress fracture and shorter stature[16] and/or higher BMI,[22] our findings are consistent with other studies that did not report such associations.[8,21,32] However, these factors appear to remain as equivocal risk factors for stress fracture and require further investigation.

The prospective design, the large sample studied, and the standardized Marine Corps training program provided us with a unique opportunity to examine the association between important characteristics and stress fractures resulting from a controlled, rigorous training that involves repetitive exercise using the lower extremities. However, this study is subject to the weaknesses of survey recall bias by study participants. To minimize recall bias, information on physical activity, menstrual, and prior injury history was collected prior to the diagnosis of a stress fracture injury. Although these findings may not generalize to all active women, they provide useful information for assessment of stress fracture risk in women undergoing Marine Corps basic training.

In summary, this prospective study of 2962 women during Marine Corps basic training documents stress fractures as a significant source of morbidity. Several risk factors were significantly associated with subsequent occurrence of overall stress fracture, including baseline fitness (slow run time) and menstrual dysfunction (no menses in past year). In addition, this study found that slow run time and no menses in the past year were associated with

pelvic/femoral stress fracture. We suggest that the identification of a risk profile for injury, specifically stress fractures, is a necessary step toward the development of an effective intervention. The risk profile data developed in the current study could be an integral part of a future intervention study, such as gradual increases in physical activity, encouragement of sport activities prior to entering a military training program, and possible medical intervention for better regulation of menstrual cycles.

REFERENCES

1. Altarac M, Gardner JW, Popovich RM, et al. Cigarette smoking and exercise-related injuries among young men and women. *Am J Prev Med*. 2000;18:96-102.
2. Barrow GW, Saha S. Menstrual irregularity and stress fractures in collegiate female distance runners. *Am J Sports Med.* 1988;16:209-216.
3. Beck TJ, Ruff CB, Mourtada FA, et al. Dual-energy x-ray absorptiometry derived structural geometry for stress fracture prediction in male U.S. Marine Corps recruits. *J Bone Miner Res.* 1996;11:645-653.
4. Beck TJ, Ruff CB, Shaffer RA, et al. Stress fracture in military recruits: gender differences in muscle and bone susceptibility factors. *Bone*. 2000;27:437-444.
5. Bell NS, Amoroso PJ, Yore MM, et al. Self-reported risk-taking behaviors and hospitalization for motor vehicle injury among active duty Army personnel. *Am J Prev Med.* 2000;18:85-95.
6. Bell NS, Mangione TW, Hemenway D, et al. High injury rates among female Army trainees: a function of gender? *Am J Prev Med.* 2000;18:141-146.
7. Bennell KL, Brukner PD. Epidemiology and site specificity of stress fractures. *Clin Sports Med.* 1997;16:179-196.
8. Bennell KL, Malcolm SA, Thomas SA, et al. Risk factors for stress fractures in track and field athletes. A twelve-month prospective study. *Am J Sports Med.* 1996;24:810-818.
9. Bijur PE, Horodyski M, Egerton W, et al. Comparison of injury during cadet basic training by gender. *Arch Pediatr Adolesc Med.* 1997;151:456-461.
10. Brudvig TJ, Gudger TD, Obermeyer L. Stress fractures in 295 trainees: a one-year study of incidence as related to age, sex, and race. *Mil Med.* 1983;148:666-667.

11. Carbon R, Sambrook PN, Deakin V, et al. Bone density of elite female athletes with stress fractures. *Med J Aust*. 1990;153:373-376.

12. Cline AD, Jansen GR, Melby CL. Stress fractures in female Army recruits: implications of bone density, calcium intake, and exercise. *J Am Coll Nutr.* 1998;17:128-135.

13. Gardner Jr LI, Dziados JE, Jones BH, et al. Prevention of lower extremity stress fractures: a controlled trial of a shock absorbent insole. *Am J Public Health.* 1998;78:1563-1567.

14. Henderson NE, Knapik JJ, Shaffer SW, et al. Injuries and injury risk factors among men and women in U.S. Army Combat Medic Advanced individual training. *Mil Med.* 2000;165:647-652.

15. Hulkko A, Orava S. Stress fractures in athletes. *Int J Sports Med.* 1987;8:221-226.

16. Jones BH, Bovee MW, Harris JM III, Cowan DN. Intrinsic risk factors for exercise-related injuries among male and female Army trainees. *Am J Sports Med.* 1993;21:705-710.

17. Kelly EW, Jonson SR, Cohen ME, et al. Stress fractures of the pelvis in female Navy recruits: an analysis of possible mechanisms of injury. *Mil Med.* 2000;165:142-146.

18. Knapik JJ, Canham-Chervak M, Hauret K, et al. Seasonal variations in injury rates during US Army basic combat training. *Ann Occup Hyg*. 2002;46:15-23.

19. Knapik JJ, Sharp MA, Canham-Chervak M, et al. Risk factors for training-related injuries among men and women in basic combat training. *Med Sci Sports Exer.* 2001;33:946-954.

20. Lappe JM. Pathophysiology of osteoporosis and fracture. *Nurs Clin North Am.* 2001;36:393-400.

21. Lappe JM, Stegman MR, Recker RR. The impact of lifestyle factors on stress fractures in

female Army recruits. *Osteoporos Int.* 2001;12:35-42.

22. Lauder TD, Dixit S, Pezzin LE, et al. The relation between stress fractures and bone mineral density: evidence from active-duty Army women. *Arch Phys Med Rehabil.* 2000;81:73-79.

23. Lloyd T, Triantafyllou SJ, Baker ER, et al. Women athletes with menstrual irregularity have increased musculoskeletal injuries. *Med Sci Sports Exerc.* 1986;18:374-379.

24. Miller C, Major N, Toth A. Pelvic stress injuries in the athlete: management and prevention. *Sports Med.* 2003;33:1003-1012.

25. Myburgh KH, Hutchins J, Fataar AB, et al. Low bone density is an etiologic factor for stress fractures in athletes. *Ann Intern Med.* 1990;113:754-759.

26. Noakes TD, Smith JA, Lindenberg G, Wills CE. Pelvic stress fractures in long distance runners. *Am J Sports Med.* 1985;13:120-123.

27. O'Brien T, Wilcox N, Kersch T. Refractory pelvic stress fracture in a female long-distance runner. *Am J Orthop*. 1995;24:710-713.

28. Otis CL, Drinkwater B, Johnson M, et al. American College of Sports Medicine position stand. The Female Athlete Triad. *Med Sci Sports Exerc.* 1997;29:i-ix.

29. Shaffer RA, Brodine SK, Almeida SA, et al. Use of simple measures of physical activity to predict stress fractures in young men undergoing a rigorous physical training program. *Am J Epidemiol.* 1999;149:236-242.

30. Snedecor MR, Boudreau CF, Ellis BE, et al. U.S. Air Force recruit injury and health study. *Am J Prev Med.* 2000;18:129-140.

31. Warren MP, Brooks-Gunn J, Hamilton LH, et al. Scoliosis and fractures in young ballet dancers. Relation to delayed menarche and secondary amenorrhea. *N Engl J Med.*

1986;314:1348-1353.

32. Winfield AC, Moore J, Bracker M, et al. Risk factors associated with stress reactions in female Marines. *Mil Med.* 1997;162:698-702.

TABLE 1

Stress Fracture Sites (N = 181) in 152 Female Marine Recruits at Parris Island

March 1995 to September 1996

ICD-9	Site	N	Percentage
5010	Pelvis, unspecified	10	
501R	Pelvis ramis	27	
501S	Pelvis sacrum	2	
	Total pelvis	**39**	**21.7%**
5610	Femur unspecified	8	
561A	Femur neck/head	11	
561B	Femur proximal 1/3rd	4	
561C	Femur mid 1/3rd	9	
561D	Femur distal 3rd	4	
	Total femur	**36**	**20.0%**
6510	Tibia unspecified	26	
651A	Tibia plateau	2	
651B	Tibia proximal 1/3rd	8	
651C	Tibia mid 1/3rd	5	
651D	Tibia distal 3rd	4	
	Total tibia	**45**	**25%**
6710	**Fibula unspecified**	**7**	**3.9%**
7010	Ankle foot unspecified	8	
7510	Calcaneous	5	
7710	Tarsal navicular	1	
	Total ankle/foot	**14**	**7.8%**
781A	1st metatarsal	2	
781B	2nd metatarsal	14	
781C	3rd metatarsal	19	
781D	4th metatarsal	4	
781E	5th metatarsal	1	
	Total metatarsal	**40**	**21.7%**
	Total fractures	**181**	**100%**

ICD-9 = *International Classification of Diseases*, 9th revision.

TABLE 2

Means and Standard Deviations of Selected Demographic and Physical Characteristics by Stress Fracture Status, 2962 Female Marine Corps Recruits, Parris Island, March 1995 to September 1996

Characteristic*	Mean (SD)					
	Stress Fracture		No Stress Fracture		Total	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Age (y)	152	19.3 (2.1)	2,808	19.2 (2.1)	2,960	19.2 (2.1)
Height (cm)	152	163.6 (6.5)	2,806	163.8 (6.5)	2,958	163.8 (6.5)
Weight (kg)	152	57.6 (6.8)	2,806	58.1 (6.7)	2,958	58.0 (6.7)
Body mass index	152	21.5 (1.9)	2,806	21.6 (1.9)	2,958	21.6 (1.9)
Age at menarche (age in y)	150	12.9 (1.4)	2,768	12.6 (1.5)	2,918	12.6 (1.5)

*For all characteristics, none of the differences between those with and without stress fractures were statistically significant ($p > 0.05$). SD = standard deviation.

TABLE 3

Stress Fracture Incidence and Odds Ratios by Measures by Demographic, Physical Body Stature, and Prior Injury Characteristics, Female Marine Corps Recruits, Parris Island, March 1995 to September 1996

Variable	**Category**	**N**	**Overall Stress Fracture Incidence (%)**	**OR (95% CI)**
Race/Ethnicity	Black	545	3.5	1.00
	White	1896	5.3	1.54 (0.9-2.5)
	Hispanic	347	6.6	**1.97 (1.1-3.7)**
	Asian	92	7.6	2.28 (0.9-5.6)
	American Indian/Other	82	3.7	1.10 (0.3-3.6)
Height (cm)	Shortest (≤157.26 cm)	355	6.2	1.30 (0.8-2.1)
	Average (163.77 cm)	2253	4.8	1.00
	Tallest (≥170.29 cm)	345	6.1	1.28 (0.8-2.1)
Weight (kg)	Lightest (≤51.47 kg)	445	6.7	1.43 (0.9-2.1)
	Average (58.17 kg)	1973	4.8	1.00
	Heaviest (≥64.87 kg)	437	4.8	1.00 (0.6-1.6)
BMI (wt/height^2)	Lowest (≤19.73)	511	5.3	1.07 (0.7-1.6)
	Average (21.67)	2013	5.0	1.00
	Highest (≥23.61)	423	5.7	1.15 (0.7-1.8)

History of stress fracture	No	2863	5.2	1.00
	Yes	74	4.1	0.78 (0.2-2.5)
History of lower extremity injury	No	1973	5.6	1.00
	Yes	968	4.3	0.77 (0.5-1.1)

OR = odds ratio; CI = confidence interval.

TABLE 4

Stress Fracture Incidence and Odds Ratios by Objective and Self-Assessed Measures of Physical Fitness and Activity, Female Marine Corps Recruits, Parris Island, March 1995 to September 1996

Variable	Category	N	Overall Stress Fracture Incidence (%)	OR (95% CI)
Timed run	Q1 Fastest	686	2.3	1.00
	Q2	705	2.8	1.22 (0.6-2.4)
	Q3	680	7.5	**3.45 (2.0-6.1)**
	Q4 Slowest	696	7.9	**3.63 (2.1-6.4)**
Self-rated fitness	Excellent-Very Good	639	3.6	1.00
	Good	1511	4.8	1.34 (0.8-2.2)
	Fair-Poor	807	6.9	**2.00 (1.2-3.3)**
Activity 2 months prior to training				
Exercise or sport participation	0-1 times weekly	312	4.8	0.91 (0.5-1.6)
	2-4 times weekly	1763	5.3	1.00
	5-7 times weekly	885	5.0	0.94 (0.7-1.4)
Change in exercise or sports	More or much more	1643	5.4	1.00 (0.7-1.4)
	Same	936	5.3	1.00
	Much less or less	374	3.7	0.69 (0.4-1.3)
Run mileage (per day)	Average $\geq$3.0 miles	462	2.8	1.00
	Average 1.5-2.99 miles	1170	4.6	1.67 (0.9-3.1)

	Nonrunner or <1.5 miles	1287	6.5	**2.41 (1.3-4.4)**
Run frequency (week)	≥4 times	914	3.8	1.00
	1-3 times	1906	5.5	1.46 (0.99-2.2)
	Nonrunner	126	7.9	**2.17 (1.0-4.5)**
Run time (minutes)	>20 minutes	635	3.9	1.00
	Nonrunner or <20 minutes	2239	5.6	1.42 (0.9-2.2)

OR = odds ratio; CI = confidence interval.

TABLE 5

Stress Fracture Incidence and Odds Ratios by Measures of Self-Reported Reproductive History, and Birth Control Use, Female Marine Corps Recruits, Parris Island, March 1995 to September 1996

Variable	Category	N	Overall Stress Fracture Incidence (%)	OR (95% CI)
Age at menarche	≤12 years old	1393	4.2%	1.00
	13 years or older	1525	6.0%	**1.44 (1.0-2.0)**
Menses (past year)*	10-12 menses	2337	5.3	1.00
	1-9 menses	407	4.2	0.77 (0.5-1.3)
	0 menses	25	24.0	**5.64 (2.2-14.4)**
Secondary amenorrhea*	Menses past 6 months	2400	5.0	1.00
	No menses past 6 months	113	8.0	1.66 (0.8-3.4)
Oral contraception	Nonuser	1021	4.9	1.00
	User	1910	5.3	1.08 (0.8-1.5)

*Women who reported being pregnant during 12 months prior to training (n = 146) were excluded from the analysis. OR = odds ratio; CI = confidence interval.

TABLE 6

Adjusted Odds Ratios for Potential Risk Factors for Overall Lower Extremity and Pelvic/Femoral Stress Fracture Incidence, 2597 Women, Parris Island Basic Training March 1995 to September 1996*

Risk Factor	**Category**	**Overall Stress Fracture AOR** (95% CI)**	**Pelvic/Femoral Stress Fracture AOR** (95%CI)**
Timed run	Q1 fastest	1.00	1.00
	Q2	1.21 (0.5-2.1)	2.37 (0.9-6.2)
	Q3	**3.41 (1.9-6.1)**	**3.89 (1.6-9.6)**
	Q4 slowest	**3.54 (2.0-6.3)**	**3.14 (1.2-9.0)**
Number of menses past year	10-12 menses	1.00	1.00
	1-9 menses	0.76 (0.4-1.3)	1.15 (0.6-2.3)
	0 menses	**3.79 (1.3-10.7)**	**5.85 (1.7-20.8)**

*Women who reported being pregnant during 12 months prior to training (n = 146) were excluded from the analysis.
**AOR: Odds ratios adjusted for all variables in the table plus age and race/ethnicity; women who were pregnant during the year prior to training have been omitted. CI = confidence interval.

REPORT DOCUMENTATION PAGE

1. Report Date (DD MM YY)	2. Report Type	3. DATES COVERED (from - to)
02-09-2004	Final	1994 - 2004

4. TITLE AND SUBTITLE
Predictors of Stress Fracture Susceptibility in Young Female Recruits

6. AUTHORS
Shaffer RA, Rauh MJ, Brodine SK, Trone DW, Macera CA

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Health Research Center
P.O. Box 85122
San Diego, CA 92186-5122

8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Chief, Bureau of Medicine and Surgery
Code M2
2300 E St NW
Washington DC 20372-5300

5a. Contract Number:
5b. Grant Number:
5c. Program Element:
5d. Project Number:
5e. Task Number:
5f. Work Unit Number: 60213
5g. IRB No. 2002-0020

9 PERFORMING ORGANIZATION REPORT NUMBER
Report No. 04-30

10. Sponsor/Monitor's Acronyms(s)
BuMed

11. Sponsor/Monitor's Report Number(s)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Published in the American Journnal of Sports Medicine, 2006, 34(1), 108-15 [Epub 2005 Sep 16]

14. ABSTRACT (maximum 200 words)

We explored pretraining characteristics that may identify women at increased risk of stress fractures during boot camp. Data collected included performance on a timed run, anthropomorphic measurements, and a baseline questionnaire highlighting exercise and health habits among 2962 women undergoing basic training at the Marine Corps Recruit Depot (MCRD), Parris Island, in 1995-96. One hundred and fifty-two recruits (5.1%) had 181 confirmed lower extremity stress fractures, with the most common sites being the tibia (25%), metatarsals (22%), pelvis (22%), and femur (20%). Logistic regression models revealed that low physical fitness (a slower time on the initial run test) and no menses during the past year were significantly associated with the occurrence of stress fractures during boot camp. These findings suggest that stress fractures may be reduced if women entering MCRD training participated in pretraining activities designed to improve aerobic fitness. Women reporting no menses during the previous year may need additional observation during training.

15. SUBJECT TERMS
fitness, injury, military

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	b. THIS PAGE			Commanding Officer
UNCL	UNCL	UNCL	UU	27	19b. TELEPHONE NUMBER (INCLUDING AREA CODE) COMM/DSN: (619) 553-8429